Induction and Transformers

Power Loss in Transmission Lines
As electric current moves through a conductor, energy is converted to many forms, including **heat**, which is considered wasted, unused or “lost”. In terms of electricity, however we usually consider the *rate* of energy delivered or lost (i.e. **power**).

Example #13: A generator at City A delivers power at 1000 kW to City B. The total resistance in the cables is only 10 ohms.

a) How much power is lost if delivered at: 5000 V; 500 000 V.

b) Determine the efficiency rating for both voltages in a).

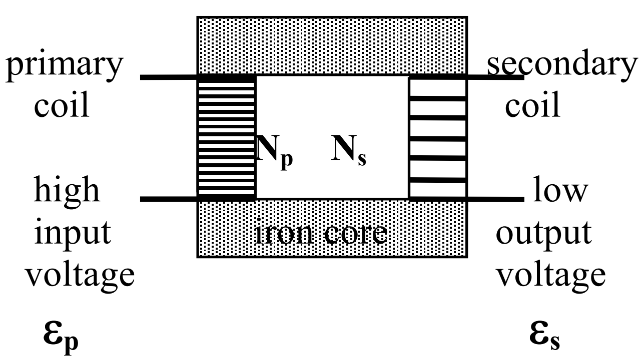
(see Induction Ex 13 for answer)

As can be seen, in order to reduce the loss of power to heat, electricity is usually delivered at *high* voltage in transmission lines from source to consumer. However, voltage arrives in our homes at 120-240 V. How does such high voltage in transmission lines get reduced? Through the use of...

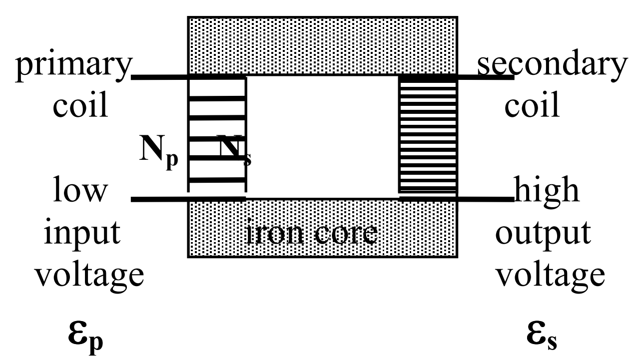
Transformers
By means of induction, these devices reduce, or “step down” the high voltages in transmission lines *before* entering homes. Transformers can also “step up” voltage for power supplys and other devices which require it.

Transformers are constructed of two coils of a different number of turns whose magnetic fields are linked by sharing a common iron core. Examine the following diagrams:

step-down transformer



step-up transformer



Transformers require AC current to function, since *only* a changing flux in the primary coil (from the changing current) can induce an EMF in the secondary coil. From Faraday's Law,

$$\varepsilon_s = -N_s \frac{\Delta\Phi}{\Delta t}$$

In turn, the changing flux *simultaneously* induces a counter (current limiting) EMF in the primary coil. If the coil's resistance is negligible, this EMF is effectively the *only* voltage drop in the primary circuit and therefore must equal the applied voltage; that is,

$$\varepsilon_p = -N_p \frac{\Delta\Phi}{\Delta t}$$

By substitution or division, we get $\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$

This is a fundamental transformer equation, which assumes 100% efficiency between power output and power input (many transformers are up to 99% efficient). This means that **power out = power in**, or

$I_p\varepsilon_p = I_s\varepsilon_s$ → $\frac{I_p}{I_s} = \frac{\varepsilon_s}{\varepsilon_p}$ → an *inverse* relationship

Note that EMF is usually written as **V** in the equations, so that

$$\boxed{\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}}$$

which is what you see on the formula sheet.

Example #14: A transformer has 50 primary turns and 2000 secondary turns. If the primary is connected to a 240 V source, and the secondary current is 2.5 mA, what is the:

a) secondary voltage?
b) primary current?
c) power output of the secondary coil?
d) power output of the primary coil?

(see Induction Ex 14 for answer)